Heating Value of Coal.

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The object of this thesis is the determination of the heat value of various samples of coal, especially those from the mines in the tract of land known as the "Northwest Property" situated at the junction of Clearfield, Centre, and Blair counties in the state of Pennsylvania, so as to determine which coal gives the best heating value for its price.

The determination of the heat value was made in a Parr Standard Colorimeter, No. 213, made by the Standard Calorimeter Co. of East Moline Illinois.

This calorimeter was chosen rather than the Carpenter as giving more uniform results as determined by the theses of Hall and Miller.

A fuel calorimeter is an instrument for the determination of the heat that

would be given up by the complete combustion of the fuel.

There are many forms of fuel calorimeters, in which the combustion takes place in atmospheric air, oxygen gas, or the oxygen is furnished by a chemical mixed with the fuel.

Any of these methods of furnishing the oxygen may be used, the only points to be ensured being that there be an excess of oxygen so that the combustion will be

complete, and that all the heat developed by the combustion be absorbed and measured or, if there is radiation, that the amount lost be known and allowed for.

The Parr Calorimeter uses the chemical method of furnishing oxygen, the chemical being sodium peroxide, which is thoroughly mixed with the fuel in the cartridge.

It is assumed that there is no radiation, although if a very exact determin-

ation is to be made the temperature of the water which absorbs the heat should be about three degrees below that of the room at the beginning of the test so that, in the rise of about four degrees, three-fourths of the rise will take place at a temperature below that of the room.

In the Parr Calorimeter the chemical is not only used to furnish the oxygen but also to absorb the products of combustion so that

no heat may be carried off by their escape.

All bomb calorimeters retain the products of combustion in the cartridge but in most cases at an exceedingly high pressure while in this case the pressure although high at first speedily drops to that of the atmosphere.

The Parr calorimeter consists of a cartridge, D, (Fig. 2), solid at one end and closed at the other by a cap, C, with which is turned a

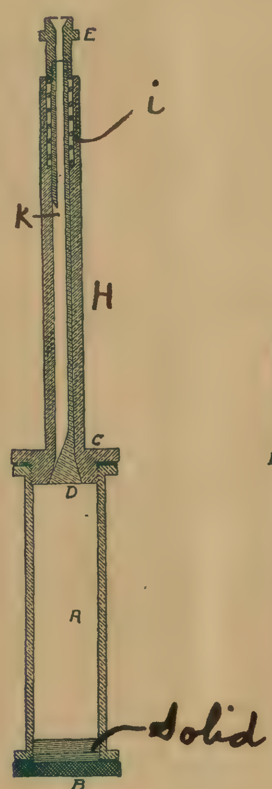

Fig. 1

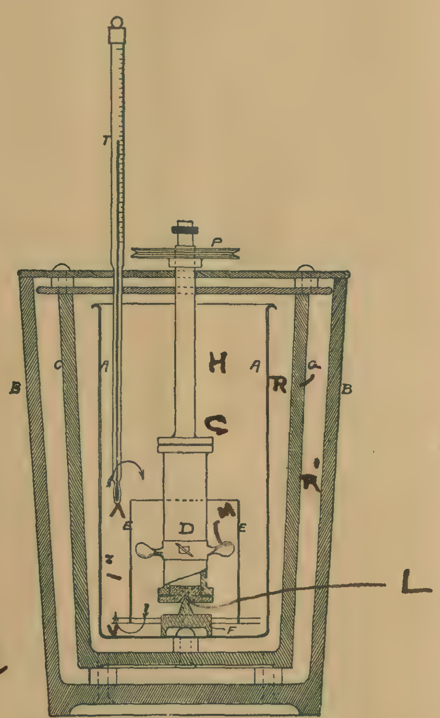

Fig. 2

stem, H, containing a valve. An enlarged section of the cartridge is shown in Fig 1, The stem of the cap is hollow as shown and contains a valve, D, with a hollow stem threaded at its upper end so that the nut, E, may be screwed onto it. The outside of this nut slides in a recess in the stem of the cap. A spring is compressed between this nut and the bottom of the recess and holds the valve shut.

The valve stem has a

hole drilled in it as far as K, below which it becomes a keyway so as to give a freer passage for the ignition wire.

The cartridge has a recess, L, Fig 2, in the bottom which fits over a pivot, F, attached to the screen, E, by three arms, on which the cartridge turns.

The cartridge has two clips snaped around it to which are attached four vanes, M, which, when the cartridge is revolved in a clockwise direction by a small electric motor,

set the water in motion in the direction shown by the arrows and thus bring it to a uniform temperature.

The cartridge and screen are contained in a can, A, together with 2000 cubic centimeters of water. This can is placed inside a fibre case, G, leaving an air space, R, between them. Outside of this is a second fibre case, B, a second air space, R', being left between the two cases. The covers for the two cases are fastened together so that they are

both removed at once and an air space is left between them.

The stem of the cartridge cap extends through the covers and has a wheel, P, slipped over it for a belt.

There is a second hole in the covers for a thermometer, T. This hole is so placed that the thermometer is contained in the can, A, between it and the screen but does not touch either. The thermometer is of a special kind reading from 65° to 90° Fahrenheit by 20ths

of a degree with a bulb of extra large capacity so that it is very sensitive.

It is kept from slipping to the bottom of the can by a rubber washer placed around the stem at the 66° mark and resting on the cover of the calorimeter. This raises the bulb about one inch from the bottom of the can; according to the directions sent with the instrument it should have been about the centre of the can so as to secure the mean tem-

perature of the water but it was then found to be top heavy and, as the temperature remains constant at its maxinum for one or two minutes before it begins to fall, very little if any error was introduced by this means.

The charge and chemical are placed in the cartridge and mixed by shaking and fired by dropping a red-hot iron wire through the valve stem and valve into them.

This wire is $2\frac{1}{2}$ milime-

ters in diameter, or No. 11 gauge, and one centimeter long. It should weigh approximately .330 grams. The wire loses very little in weight by use and can be used repeatedly.

Of course a correction must be made for the heat of the wire and this is given by the makers as .022° Fahrenheit, calculated thus:

Taking .114 as the specific heat of iron and 1200° to 1300° Fahrenheit as the temperature at a red heat, then

$$\frac{1250 \times .330 \times .114}{2123} = .022$$

2123 being the water in the can plus the wate equivalent of the calorimeter. They also state that this agrees closely with the factor obtained experimentally. A variation of 100° in the initial temperature of the wire causes a difference in the final reading of only .002° or 6 B.T.U.

Method of Operation.

The coal was broken with a hammer to about the size of pea coal. It was then placed in a box and thoroughly mixed. Portions were then taken from the four corners and the centre and placed in a coffee mill and ground into a seive with a mesh of one hundred to the inch. The seive was shaken and all that did not pass through it was removed and returned to the mill to be reground. This sifting and regrinding were con-

tinued until about ten grams had passed through the seive. This was then taken to the balance in the Electrical Laboratory and one-half gram was carefully weighed into a weighed watch glass. The method used being as follows: The watch glass was placed on the pan and balanced until the mean of the oscil-lations to the right and left was the centre mark. The weights were then increased one-half a gram and coal added until the mean of

the oscillations was again the centre mark.

After the coal was weighed the watch glass and coal were placed in a desiccator and the other samples weighed until three were secured.

The three samples were then placed in the oven, which had previously been heated to about one hundred and seven degrees Centigrade, and heated for forty-five minutes at a temperature of from one hundred and five to one hundred and ten degrees.

The temperature was read on the thermometer shown projecting into the oven. The oven was heated by a Bunsen burner which was adjusted so as to keep the temperature as near as possible constant and this was further regulated by either removing the burner when the temperature approached 110° or increasing the heat with a second burner when it fell near to 105°. If the rise in temperature did not stop at 110° for any reason, the

door of the oven was opened for a few seconds until it fell below 110°.

After heating the coal was returned to the desiccator and allowed to cool.

The calorimeter was then prepared. The flask was filled with two thousand cubic centimeters of distilled or filtered water, the filtered water being ice-water from the cooler to reduce the temperature to within the range of the thermometer.

As it was very incon-

venient to reduce the temperature of the water to 60° (the temperature at which the flask was graduated) every time it was to be measured, the flask was regraduated for a temperature of 70° by cooling the water to 60° and measuring it and then heating it to 70° and marking the stem; measurements being in each case made to the bottom of the meniscus.

The can was then removed from the calorimeter

and the water poured in. The outside of the can and the inside of the inner fibre pail were carefully dried, as the presence of a very small quantity of water in the air spaces will increase the radiation so as to throw the results entirely out.

The cap was then removed from the cartridge and the coal from one of the crystals swept into it with a camel's-hair brush, the cartridge being stood on a clean piece of paper so that any coal that may be spilt

may be swept into the cartridge.

The measure for the chemical is then filled and the chemical poured into the cartridge.

The measure is made to hold about 8½ or 9 grams of chemical so that there is 17 or 18 times as much chemical as coal.

The cap was then screwed on firmly and the cartridge shaken to mix the contents, a finger being held against the nut of the valve stem so that

there is no danger of the mixture getting into the valve. It is then rapped on the table to settle the charge and jar down any particles that might have stuck to the sides and the valve tried to see that it works easily.

The vanes are placed on the cartridge and the whole placed in the can and the cover put on. The pulley is then dropped onto the stem, the belt put on, and the motor started.

A rubber washer is placed

around the thermometer at the 66° mark, to prevent it from slipping too far into the calorimeter, and the thermometer inserted through its hole into the instrument.

The calorimeter is then allowed to stand for two or three minutes until the temperature becomes constant by the circulation of the water and the thermometer is then read.

One of the ignition wires is then heated as hot as possible in the Bunsen flame and dropped into

the hole in the valve stem and the valve pressed down and released as quickly as possible. The ignition of the charge is indicated by a jet of yellow smoke which shoots out before the valve closes and by a rapid rise of the temperature.

The combustion takes about four or five minutes before a maximum temperature is reached, indicating the completion of the combustion. This temperature is noted.

If, as was sometimes the case, the temperature shoots up to a maximum in a quarter second or so and then drops, finally rising again, the second maximum is the one taken as this phenomenon was supposed to be due to the fact that the water did not circulate fast enough and that the temperature around the thermometer and cartridge rose first and then fell as the water circulated, finally rising again as the com-

bustion was completed.

When the temperature began to fall from the final value, the motor was stopped, the thermometer removed and placed in its box, the cartridge taken out and the vanes and cap removed. It was then placed under the hot water spigot and filled with hot water to disolve out the chemical which was always left in the cartridge.

The products of combustion were all soluble

in hot water.
After the cartridge is clean it is dried with a cloth and is then ready for a new charge.
In the meanwhile the can was removed and the water poured into the flask and enough water added to make up for that lost by adhesion to the cartridge. In the last ten or twelve determinations a good deal of water was removed and the flask filled up with ice water from the filter so as to

to keep the temperature down within the limits of the thermometer.

The thermometer was read to one hundredths of a degree, one fifth of a division, by means of a reading glass on a long handle, care being taken to have the top of the mercury in a line with the centre of the glass and to avoid parallax by keeping the divisions on the thermometer over their reflections in the mercury.

Great care had to be taken not to get any of the chemical on the hands or in the nose as it is of an extremely caustic nature.

Working up the Results.

The difference between the final temperature, "Temperature After", and the initial temperature, "Temperature Before", minus the correction factor, .022° was multiplied by the

factor 3100 giving as a result the British Thermal Units per pound of coal.

3100 times the average of the corrected differences for each kind of coal was taken as the heat value of that coal.

The factor 3100 is determined as follows: The water used plus the water equivalent of the calorimeter amounts to 2123.5 grams. Now it has been found that only .73 of the heat de-

veloped comes from the combustion of the coal the other .27 coming from the heat of combination of the products of combustion, CO_2 and H_2O, with the chemical.

If one-half gram of coal causes 2123.5 grams of water to rise $r°$ in temperature, an equal weight of coal would raise the temperature $(2 \times 2123 \times "r")°$ and one pound of coal would raise one pound of water the same amount or $(2 \times 2123 \times "r")°$.

Now a British Thermal Unit is the heat required to raise one pound of water one degree Fahrenheit.

Therefore, as only .73 of the heat comes from the combustion of the coal, one pound of coal would give the water (2 x 2123 x .73 x "r") B.T.U. 2 x 2123 x .73 = 3100

Hence the B.T.U. per pound of coals equals 3100 r.

Coal Tested.

#2. Westmoreland Co. Pa.
Pea Anthracite. Mined by the
"Apollo Coal Co.", West
Penn Branch P. R. R.

#4. Semi-Bituminous
Bernice Coal from Sul-
livan Co., Pa. Mine on
the Williamsport and North
Branch R. R.

#5. Mammoth Veine
Anthracite. From the
"Stanton Colliery" of the
Brookwood Coal Co., Ma-

hanoy Plane above Pottsville.

#6. Bituminous Coal. From the "A Seam" of the "Pioneer Colliery", near Osceola, Centre Co., Pa.

#7 Bituminous Coal. From the "B Seam or Miller" of the "Eureka No. 28" shaft. On the property of the Kittoning Coal Co., Clearfield Co., Pa.

#8. Bituminous Coal. From the "D Seam" or "Moshannon" of "Atlantic No. 1" Colliery,

West Moshannon, Clearfield Co., Pa.

#9. Bituminous Coal. From the "E Seam" or "Cap" of the colliery operated by Henry Siveright, near Osceola, Clearfield Co., Pa.

#10. Bituminous Coal. From the "C Seam" of the "Monroe Colliery", on the property of the Kittaning Coal Co., near Osceola, Clearfield Co., Pa.

The bituminous coals were easily broken in the hand.

They broke in strata and ground easily.

No. 2 contained considerable rock slack which the mill would not break.

No. 5 had a bright appearance both before and after grinding.

The samples of the last six coals were each one big lump, that of No. 5 weighing about six pounds and each of the others about ten or fifteen pounds.

No. 4 was in two lumps about the size of hen's eggs.

Coal #2

Observation	Temperature Before	Temperature After	Corrected Difference
1	82.85	87.30	4.43
2	79.20	83.68	4.46
3	77.87	82.40	4.51

Average 4.47

B.T.U. per lb. of Coal 13857

Coal #4

Observation	Temperature Before	Temperature After	Corrected Difference
1	74.45	78.90	4.43
2	75.86	80.45	4.57
3	73.07	77.65	4.56

Average 4.52

B.T.U. per lb. of Coal 14012

Coal # 5

Observation	Temperature Before	After	Corrected Difference
1	69.55	73.94	4.37
2	75.20	79.60	4.38
3	78.08	82.48	4.38

Average 4.38

B.T.U. per lb. of Coal 13578

Coal # 6

Observation	Temperature Before	After	Corrected Difference
1	81.42	86.22	4.77*
2	69.53	74.36	4.80*
3	71.25	76.08	4.81

* Copper wire correction .03° Average 4.79

B.T.U. per lb. of Coal 14849

Coal # 7

Observation	Temperature Before	After	Corrected Difference
1	78.44	82.95	4.49
2	71.57	76.11	4.52
3	77.14	81.64	4.48

Average 4.50

B. T. U. per lb. of Coal 13950

Coal # 8

Observation	Temperature Before	After	Corrected Difference
1	82.05	86.80	4.73
2	80.00	84.77	4.75
3	78.15	82.94	4.77

Average 4.75

B. T. U. per lb. of Coal 14825

Coal # 9

Observation	Temperature Before	After	Corrected Difference
1	77.09	81.79	4.68
2	78.00	82.75	4.73
3	79.31	83.97	4.64

Average 4.68

B. T. U. per lb. of Coal 14508

Coal #10

Observation	Temperature Before	After	Corrected Difference
1	82.45	86.77	4.30
2	81.24	85.55	4.29
3	83.25	87.55	4.28

Average 4.29

B. T. U. per lb. of Coal 13299

Summary

Coal Number	B. T. U. Found	Given	Authority
2	13857	14121	Kent
4	14012	13562	"
5	13578	13732	Poole
6	14849	14752	Kent
7	13950		
8	14825		
9	14508		
10	13299		
Average Clearfield Coal (last four)	14146	15002	Kent

Conclusions.

From this it is seen that the samples of bituminous coal, with one exception gave considerably higher heat values than the anthracite.

All these kinds of bituminous coal sell for the same price and therefore it would seem that the A seam coal from the Pioneer colliery near Osceola, Centre Co., Pa. was the most economical with the D seam or "Moshannon" coal from the "Atlantic No. 1" colliery, in West Moshon-

non, Clearfield Co., Pa. a close second, while the C seam was very much inferior, being even worse than the anthracite coals.

From the comparisions of the heat values obtained with those given by Kent and Poole as the averages for the different kinds of coal it is seen that, with one exception (No. 4), the calorimeter gives heat values which are nearly the same but a little lower.

1. Measuring flask. 2. Oven. 3. Calorimeter
4. Oven thermometer. 5. Calorimeter thermometer.
6. Chemical measure. 7. Pliers to hold wire.
8. Motor. 9. Lamps in series with the motor to furnish resistance. (They are in parallel with each other. 10. Bunsen burner.
11. Reading glass.